DEFENSE ADVANCED RESEARCH PROJECTS AGENCY (DARPA)
15.1 Small Business Innovation Research (SBIR)

1.1 INTRODUCTION

DARPA's mission is to prevent technological surprise for the United States and to create technological surprise for its adversaries. The DARPA SBIR and STTR Programs are designed to provide small, high-tech businesses and academic institutions the opportunity to propose radical, innovative, high-risk approaches to address existing and emerging national security threats; thereby supporting DARPA's overall strategy to bridge the gap between fundamental discoveries and the provision of new military capabilities.

The responsibility for implementing DARPA's Small Business Innovation Research (SBIR) Program rests with the Small Business Programs Office.

DEFENSE ADVANCED RESEARCH PROJECTS AGENCY
Attention: DIRO/SBPO
675 North Randolph Street
Arlington, VA 22203-2114
sbir@darpa.mil
Home Page http://www.darpa.mil/Opportunities/SBIR_STTR/SBIR_STTR.aspx

Offerors responding to the DARPA topics listed in Section 12.0 of the DoD 15.1SBIR Solicitation must follow all the instructions provided in the DoD Program Solicitation. Specific DARPA requirements in addition to or that deviate from the DoD Program Solicitation are provided below and reference the appropriate section of the DoD Solicitation.

3.0 DEFINITIONS

3.4 Export Control

The following will apply to all projects with military or dual-use applications that develop beyond fundamental research (basic and applied research ordinarily published and shared broadly within the scientific community):

(1) The Contractor shall comply with all U. S. export control laws and regulations, including the International Traffic in Arms Regulations (ITAR), 22 CFR Parts 120 through 130, and the Export Administration Regulations (EAR), 15 CFR Parts 730 through 799, in the performance of this contract. In the absence of available license exemptions/exceptions, the Contractor shall be responsible for obtaining the appropriate licenses or other approvals, if required, for exports of (including deemed exports) hardware, technical data, and software, or for the provision of technical assistance.

(2) The Contractor shall be responsible for obtaining export licenses, if required, before utilizing foreign persons in the performance of this contract, including instances where the work is to be performed on-site at any Government installation (whether in or outside the United States), where the foreign person will have access to export-controlled technologies, including technical data or software.

(3) The Contractor shall be responsible for all regulatory record keeping requirements associated with the use of licenses and license exemptions/exceptions.

(4) The Contractor shall be responsible for ensuring that the provisions of this clause apply to its subcontractors.

Please visit http://www.pmddtc.state.gov/regulations_laws/itar.html for more detailed information regarding ITAR/EAR requirements.

3.5 Foreign National

Foreign Nationals (also known as Foreign Persons) means any person who is NOT:

a. a citizen or national of the United States; or
b. a lawful permanent resident; or
c. a protected individual as defined by 8 U.S.C. § 1324b

ALL offerors proposing to use foreign nationals MUST follow section 5.4. c.(8) of the DoD Program Solicitation and disclose this information regardless of whether the topic is subject to ITAR restrictions. There are two ways to obtain U.S. citizenship: by birth or by naturalization. Additional information regarding U.S. citizenship is available at http://travel.state.gov/law/citizenship/citizenship_782.html. Definitions for "lawful permanent resident" and "protected individual" are available under section 3.5 of the DoD instructions.

4.0 PROPOSAL FUNDAMENTALS

PLEASE NOTE: Use of the DARPA SBIR/STTR Information Portal (SSIP) is MANDATORY. Offerors will be required to authenticate into the SSIP (via the DARPA Extranet) to retrieve their source selection decision notice, to request debriefings, and to upload reports (awarded contracts only). DARPA SBPO will automatically create an extranet account for new users and send the SSIP URL, authentication credentials, and login instructions AFTER the 15.1source selection period has closed. DARPA extranet accounts will ONLY be created for the individual named as the Corporate Official (CO) on the proposal coversheet. Offerors may not request accounts for additional users at this time.

4.6 Classified Proposals

DARPA topics are unclassified; however, the subject matter may be considered to be a "critical technology" and therefore subject to ITAR/EAR restrictions. See **Export Control** requirements above in Section 3.1.

4.10 Debriefing

DARPA will provide a debriefing to the offeror in accordance with FAR 15.505. The source selection decision notice (reference 4.4 Information on Proposal Status) contains instructions for requesting a proposal debriefing. Please also refer to section 4.0 of the DoD Instructions.

Notification of Proposal Receipt

Within 5 business days after the solicitation closing date, the individual named as the "Corporate Official" on the Proposal Cover Sheet will receive a separate e-mail from sbir@darpa.mil acknowledging receipt for each proposal received. Please make note of the topic number and proposal number for your records.

Information on Proposal Status

The source selection decision notice will be available no later than **90 days after solicitation close.** The individual named as the "Corporate Official" on the Proposal Cover Sheet will receive an email for each proposal submitted, from sbir@darpa.mil with instructions for retrieving their official notification from the SSIP. Please read each notification carefully and note the proposal number and topic number referenced. The CO must retrieve the letter from the SSIP 30 days from the date the e-mail is sent. After 30 days the CO must make a written request to sbir@darpa.mil for source selection decision notice. The request must explain why the offeror was unable to retrieve the source selection decision notice from the SSIP within the original 30 day notification period. Please also refer to section 4.0 of the DoD Instructions.

4.13 Phase I Award Information

a. Number of Phase I Awards. The number of Phase I awards will be consistent with DARPA's budget, the number of anticipated awards for interim Phase I modifications, and the number of anticipated Phase II contracts. No Phase I contracts will be awarded until evaluation of all qualified proposals for a specific topic is completed. Normally offerors will receive their source selection decision notice for a Phase I award within 90 days of the closing date for this solicitation. Selections are posted at www.dodsbir.net/selections.
b. Type of Funding Agreement. DARPA Phase I awards will be Firm Fixed Price contracts.
c. Dollar Value. DARPA Phase I awards shall not exceed $100,000 for the base effort, or $105,000 for the base effort if technical assistance services are proposed, and shall not exceed $50,000 for the option if exercised.
d. Timing. Across DoD, the median time between the date that the SBIR solicitation closes and the award of a Phase I contract is approximately four months.

4.22 Discretionary Technical Assistance (DTA)

Offerors that are interested in proposing use of a vendor for technical assistance must complete the following:

1. Provide a one-page description of the vendor you will use and the technical assistance you will receive. The description should be included as the LAST page of the Technical Volume. This description will not count against the 20-page limit of the technical volume and will NOT be evaluated.
2. Input the total proposed DTA cost under the "Discretionary Technical Assistance" line along with a detailed cost breakdown under "Explanatory material relating to the cost proposal" via the online cost proposal. The proposed amount may not exceed $5,000. You may also submit the detailed cost breakdown as an appendix to the one-page description. Label this appendix "DTA COST Breakdown" – it will not count against the 20-page limit of the technical volume.

Approval of technical assistance is not guaranteed and is subject to review of the Contracting Officer. Please see section 4.22 of the DoD instructions for additional information.

5.0 PHASE I PROPOSAL

Phase I Option

DARPA has implemented the use of a Phase I Option that may be exercised to fund interim Phase I activities while a Phase II contract is being negotiated. Only Phase I companies selected for Phase II will be eligible to exercise the Phase I Option. The Phase I Option covers activities over a period of up to four months and should describe appropriate initial Phase II activities that may lead to the successful demonstration of a product or technology. The statement of work for the Phase I Option counts toward the 20-page limit for the Technical Volume.

A Phase I Cost Volume ($155,000 maximum) must be submitted in detail online via the DoD SBIR/STTR submission system. Offerors that participate in this solicitation must complete the Phase I Cost Volume, not to exceed the maximum dollar amount of $100,000, or $105,000 if technical assistance services are proposed, and a Phase I Option Cost Volume, not to exceed the maximum dollar amount of $50,000. Phase I awards and options are subject to the availability of funds.

Offerors are REQUIRED to use the online Cost Volume for the Phase I and Phase I Option costs (available on the DoD SBIR/STTR submission site).

Human or Animal Subject Research

DARPA discourages offerors from proposing to conduct Human or Animal Subject Research during Phase I due to the significant lead time required to prepare the documentation and obtain approval, which will delay the Phase 1 award. See sections 4.7 and 4.8 of the DoD Instructions for additional information.

5.4 (6) Commercialization Strategy

DARPA is equally interested in dual use commercialization of SBIR project results to the U.S. military, the private sector market, or both, and expects explicit discussion of key activities to achieve this result in the commercialization strategy part of the proposal. The discussion should include identification of the problem, need, or requirement relevant to a Department of Defense application and/or a private sector application that the SBIR project results would address; a description of how wide-spread and significant the problem, need, or requirement is; and identification of the potential DoD end-users, Federal customers, and/or private sector customers who would likely use the technology.

Technology commercialization and transition from Research and Development activities to fielded systems within the DoD is challenging. Phase I is the time to plan for and begin transition and commercialization activities. The small business must convey an understanding of the preliminary transition path or paths to be established during the Phase I project. That plan should include the Technology Readiness Level (TRL) expected at the end of the Phase I. The plan should include anticipated business model and potential private sector and federal partners the company has identified to support transition and commercialization activities. In addition, key proposed milestones anticipated during Phase II such as: prototype development, laboratory and systems testing, integration, testing in operational environment, and demonstrations.

5.5 Phase I Proposal Checklist:

The following criteria must be met or your proposal may be REJECTED.

____1. Include a header with company name, proposal number and topic number to each page of your Technical Volume.
____2. Include tasks to be completed during the option period and include the costs in the Cost Volume.
____3. Break out subcontractor, material and travel costs in detail. Use the "Explanatory Material Field" in the DoD Cost Volume for this information, if necessary.
____4. The base effort does not exceed $100,000, or $105,000 if technical assistance services are proposed, and six months and the option does not exceed $50,000 and four months. The costs for the base and option are clearly separate, and identified on the Proposal Cover Sheet, in the Cost Volume, and in the statement of work section of the Technical Volume.
____5. The technical volume does not exceed twenty (20) pages. Any page beyond 20 will be redacted prior to evaluations.

____6. Upload the Volume 1: Proposal Cover Sheet; Volume 2: Technical Volume; Volume 3: Cost Volume; and Volume 4: Company Commercialization Report electronically through the DoD submission site by 6:00 AM (ET) on February 18, 2015.
____7. After uploading your file on the DoD submission site, review it to ensure that all pages have transferred correctly and do not contain unreadable characters. Contact the DoD Help Desk immediately with any problems.

6.0 PHASE I EVALUATION CRITERIA

Phase I proposals will be evaluated in accordance with the criteria in section 6.0 of the DoD solicitation.

The offeror's attention is directed to the fact that non-Government advisors to the Government may review and provide support in proposal evaluations during source selection. Non-government advisors may have access to the offeror's proposals, may be utilized to review proposals, and may provide comments and recommendations to the Government's decision makers. These advisors will not establish final assessments of risk and will not rate or rank offeror's proposals. They are also expressly prohibited from competing for DARPA SBIR or STTR awards in the SBIR/STTR topics they review and/or provide comments on to the Government. All advisors are required to comply with procurement integrity laws and are required to sign Non-Disclosure and Rules of Conduct/Conflict of Interest statements. Non-Government technical consultants/experts will not have access to proposals that are labeled by their offerors as "Government Only".

Please note that qualified advocacy letters will count towards the proposal page limit and will be evaluated towards criterion C. Advocacy letters are not required. Consistent with Section 3-209 of DoD 5500.7-R, Joint Ethics Regulation, which as a general rule prohibits endorsement and preferential treatment of a non-federal entity, product, service or enterprise by DoD or DoD employees in their official capacities, letters from government personnel will NOT be accepted.

A qualified advocacy letter is from a relevant commercial procuring organization(s) working with a DoD or other Federal entity, articulating their pull for the technology (i.e., what need the technology supports and why it is important to fund it), and possible commitment to provide additional funding and/or insert the technology in their acquisition/sustainment program. If submitted, the letter should be included as the last page of your technical proposal. Advocacy letters which are faxed or e-mailed separately will NOT be accepted.

Limitations on Funding

DARPA reserves the right to select and fund only those proposals considered to be of superior quality and highly relevant to the DARPA mission. As a result, DARPA may fund multiple proposals in a topic area, or it may not fund any proposals in a topic area.

7.0 PHASE II PROPOSAL

All offerors awarded a Phase I contract under this solicitation will receive a notification letter with instructions for preparing and submitting a Phase II Proposal and a deadline for submission. Visit http://www.darpa.mil/Opportunities/SBIR_STTR/SBIR_Program.aspx for more information regarding the Phase II proposal process.

Direct to Phase II

15 U.S.C. §638(cc), as amended by NDAA FY2012, Sec. 5106, PILOT TO ALLOW PHASE FLEXIBILITY, allows the Department of Defense to make an award to a small business concern under Phase II of the SBIR program with respect to a project, without regard to whether the small business concern was provided an award under Phase I of an SBIR program with respect to such project.

DARPA is conducting a "Direct to Phase II" pilot implementation of this authority for this 15.1SBIR solicitation only and does not guarantee the pilot will be offered in future solicitations. Each eligible topic will indicate what documentation is required to determine if Phase I feasibility has been met and the technical requirements for a Direct to Phase II proposal.

Not all DARPA topics are eligible for a Direct to Phase II award. Offerors must choose between submitting a Phase I proposal OR a Direct to Phase II proposal, and may not submit both for the same topic. DARPA reserves the right to not make any awards under the Direct to Phase II pilot. All other instructions remain in effect. Direct to Phase II proposals must follow the steps outlined below:

STEP 1:

1. Offerors must create a Phase I coversheet using the DoD Phase I Proposal submission system (follow the DoD Instructions for the Cover Sheet located in section 5.4.a).
2. Offerors must upload the documentation that satisfies the Phase I feasibility requirement* (upload this documentation in the DoD Phase I Proposal submission system as the “Technical Volume” – DO NOT follow the technical volume format specified in the solicitation instructions for your justification).
    a. Maximum page length for feasibility documentation is 75 pages. If you have references, include a reference list or works cited list as the last page of the feasibility documentation. This will count towards the page limit.
    b. Work submitted within the feasibility documentation must have been substantially performed by the offeror and/or the principal investigator (PI).
    c. If technology in the feasibility documentation is subject to IP, the offeror must have IP rights. Refer to section 11.5 of the DARPA instructions for additional information.
    d. Include a one page summary on Commercialization Potential addressing the following:
        1. Does the company contain marketing expertise and, if not, how will that expertise be brought into the company?
        2. Describe the potential for commercial (Government or private sector) application and the benefits expected to accrue from this commercialization.
    e. DO NOT INCLUDE marketing material. Marketing material will NOT be evaluated and WILL be redacted.
3. Offerors DO NOT upload a Phase I Cost Volume.
4. **The Phase I Cover Sheet and applicable documentation must be submitted to http://dodsbir.com/submission by 6:00 a.m. (ET) on February 18, 2015.**

STEP 2:

1. Offerors must submit a Phase II proposal using the DARPA Phase II proposal instructions available as an attachment to the solicitation, titled DARPA SBIR/STTR Phase II Proposal Preparation Instructions, dated November 1, 2014.
2. The Phase II proposal must be submitted by 6:00 a.m. (ET), February 18, 2015.

* NOTE: Offerors are required to provide information demonstrating that the scientific and technical merit and feasibility has been established. **DARPA will not evaluate the offeror's related Phase II proposal if it determines that the offeror has failed to demonstrate that technical merit and feasibility has been established or the offeror has failed to demonstrate that work submitted in the feasibility documentation was substantially performed by the offeror and/or the principal**

investigator (PI). Refer to the Phase I description (within the topic) to review the minimum requirements that need to be demonstrated in the feasibility documentation. If you have received a Phase I award for similar work, you are ineligible to participate in this pilot program. Please contact our office at sbir@darpa.mil for additional information regarding the Phase II adoption process.

11.0 CONTRACTUAL CONSIDERATIONS

11.1(f) Publication Approval (Public Release)

National Security Decision Directive (NSDD)189 established the national policy for controlling the flow of scientific, technical, and engineering information produced in federally funded fundamental research at colleges, universities, and laboratories. The directive defines fundamental research as follows: "Fundamental research" means basic and applied research in science and engineering, the results of which ordinarily are published and shared broadly within the scientific community, as distinguished from proprietary research and from industrial development, design, production, and product utilization, the results of which ordinarily are restricted for proprietary or national security reasons."

It is DARPA's goal to eliminate pre-publication review and other restrictions on fundamental research except in those exceptional cases when it is in the best interest of national security. Please visit http://www.darpa.mil/NewsEvents/Public_Release_Center/Public_Release_Center.aspx for additional information and applicable publication approval procedures.

11.4 Patents

Include documentation proving your ownership of or possession of appropriate licensing rights to all patented inventions (or inventions for which a patent application has been filed) that will be utilized under your proposal. If a patent application has been filed for an invention that your proposal utilizes, but the application has not yet been made publicly available and contains proprietary information, you may provide only the patent number, inventor name(s), assignee names (if any), filing date, filing date of any related provisional application, and a summary of the patent title, together with either: (1) a representation that you own the invention, or (2) proof of possession of appropriate licensing rights in the invention. Please see section 11.4 of the DoD instructions for additional information.

11.5 Intellectual Property Representations

Provide a good faith representation that you either own or possess appropriate licensing rights to all other intellectual property that will be utilized under your proposal. Additionally, proposers shall provide a short summary for each item asserted with less than unlimited rights that describes the nature of the restriction and the intended use of the intellectual property in the conduct of the proposed research. Please see section 11.5 of the DoD instructions for information regarding technical data rights.

11.7 Phase I Reports

All DARPA Phase I awardees are required to submit reports in accordance with the Contract Data Requirements List – CDRL and any applicable Contract Line Item Number (CLIN) of the Phase I contract. Reports must be provided to the individuals identified in Exhibit A of the contract. Please also reference section 4.0 of the DoD Preface.

DARPA SBIR 15.1 Topic Index

SB151-001	Socket Diagnostic Tool Innovation for Upper Extremity Prostheses
SB151-002	Lightweight, Man-Portable, Low-Power Individual Water Purification System
SB151-003	Secure Software Components Leveraging the seL4 Microkernel
SB151-004	Programming New Computers
SB151-005	Collaborative Interference Cancellation for Group Communications
SB151-006	Miniature Optical Guidance & Navigation

DARPA SBIR 15.1 Topic Descriptions

SB151-001 TITLE: Socket Diagnostic Tool Innovation for Upper Extremity Prostheses

TECHNOLOGY AREAS: Biomedical, Sensors

This topic is eligible for the DARPA Direct to Phase II Pilot Program. Please see section 7.0 of the DARPA instructions for additional information. To be eligible, offerors are required to provide information demonstrating the scientific and technical merit and feasibility of a Phase I project. DARPA will not evaluate the offeror's related Phase II proposal where it determines that the offeror has failed to demonstrate the scientific and technical merit and feasibility of the Phase I project. Offerors must choose between submitting a Phase I proposal OR a Direct to Phase II proposal, and may not submit both for the same topic. Work submitted within the feasibility documentation must have been substantially performed by the offeror and/or the principal investigator (PI).

OBJECTIVE: Investigate, develop, and validate diagnostic tools to improve socket design, fitting, and real-time adjustment that will enable the deployment of advanced upper extremity prosthetics.

DESCRIPTION: Prosthetists face significant challenges when designing the socket and suspension systems that hold prostheses on upper-limb amputees. Variations among individuals introduce unique complexities that factor into fitting the socket; these include muscle bundles, neuroma, bone spurs, and skin conditions such as scars from burns and sores from infections. Due to the difficulty of measuring socket interface characteristics without disturbing the secure fit of the socket, there is a lack of quantifiable diagnostic fitment information available to prosthetists. As a result, the process of fitting sockets is currently a labor-intensive, manual approach practiced by artisans. Current fitting techniques often yield sockets that are uncomfortable, unstable, or impede full range of motion, resulting in compromised device performance or election by the amputee to not use the prosthesis altogether.

To address these challenges, DARPA seeks the development of innovative diagnostic tools for quantifying characteristics of the socket-limb interface during the fitting process, and the means of manufacturing these tools. The proposer will develop the tools for a systematic socket-fitting strategy that yields reliable and reproducible socket fitment. The tools must be able to report the interface characteristics within the socket and inform the positioning of socket components to ensure comfortable fit throughout the conduct of daily activities by the user, in particular providing a stable platform that can achieve a near-natural range of motion. The benefits to the DoD and the Warfighter include: increased usage and functionality of advanced upper-arm prostheses, a decrease in the number of required visits to a prosthetist for refitting or training in usage and donning, and the ability to return to work or service.

PHASE I: Develop a detailed preliminary design concept for diagnostic component technologies needed to measure critical socket-residual limb interface phenomena. Phase I deliverables will include: 1) a proposed toolkit, 2) a strategy for the manufacturing and deployment of its core technologies, and 3) metrics that relate the socket fitment diagnostic tools to performance of the prosthesis.

PHASE II: Finalize the design and develop the operational diagnostic tools for the manufacture and fitment of custom upper-limb sockets. Conduct tool validation trials at three or more test sites with trans-radial, trans-humeral, and shoulder disarticulation amputees and record diagnostic measurements to correlate with outcome measurements of socket and prosthesis performance. Phase II deliverables will include: 1) operational diagnostic tools, 2) quantified results of diagnostic measurements taken during upper limb socket fitting trials, and 3) analytic comparisons of the impact of diagnostic tools on socket performance and prosthesis performance. The Phase II final report should describe the approach used to develop diagnostic tools that accounted for the unique characteristics of upper-limb amputees and explain considerations for adapting the approach to fitting lower-limb systems, as well as designs for the fitment tools and associated manufacturing plans.

DIRECT TO PHASE II - Offerors interested in submitting a Direct to Phase II proposal in response to this topic must provide documentation to substantiate that the scientific and technical merit and feasibility described in the Phase I section of this topic has been met and describes the potential commercial applications. Documentation should include all relevant information including, but not limited to: technical reports, test data, prototype designs/models, and performance goals/results. Read and follow section 7.0 of the DARPA Instructions. Work submitted within the feasibility documentation must have been substantially performed by the offeror and/or the principal investigator (PI).

PHASE III: Commercial and military applications will focus on deploying the socket fitting toolkit to model sites across the country to ensure successful introduction of advanced prosthetic arm systems such as those developed by the DARPA Revolutionizing Prosthetics program. The tools must be designed for manufacturability and reproducibility, and--given the high level of anticipated complexity, sensorization, and tolerancing--require a focused effort on manufacturing methods to ensure a repeatable deployment process to the model sites. By providing model sites with these fitment technologies, they will be able to address the unique challenges of fitting prostheses to upper-arm amputees in a systematic way. Proper socket fit will allow the user to access the full range of capabilities of the advanced arm systems while avoiding socket discomfort, thus enhancing user acceptance. The model sites will establish the precedent for socket and prosthetic fitment, which will propagate to additional sites as driven by the user community.

REFERENCES:
1. Resnik, L., Klinger, S., and Etter, K. "The DEKA Arm: Its features, functionality, and evolution during the Veterans Affairs Study to optimize the DEKA Arm", Prosthetics and Orthotics International 2013, doi: 10.1177/0309364613506913.

2. Pasquina, P. and Cooper, R. Care of the Combat Amputee. Office of the Surgeon General, U.S. Army, 2009.

KEYWORDS: Advanced prosthetic arm system, upper extremity, socket fitting

SB151-002 TITLE: Lightweight, Man-Portable, Low-Power Individual Water Purification System

TECHNOLOGY AREAS: Materials/Processes, Human Systems

OBJECTIVE: Develop a lightweight, man-portable, low-power, individual water purification system that will produce 40 liters of potable water per day from any water source to include heavily polluted (chemicals, biological, heavy metals), brackish and salt water.

DESCRIPTION: There is a critical military need to introduce a capability to make potable water from any water source encountered in the battlefield to reduce the supply chain pressure caused by moving water for consumption. An active special operator can expel 2 liters of water per hour from sweating alone depending on the environment. This equates to 20 to 24 kilograms of water they must carry for each day they will be in the field without re-supply. Although technology exists that will purify water in certain environments to the United States Environmental Protection Agency (U.S. EPA) Standards for Microbiological Purifiers (bacterial removal to 6 logs, viral removal to 4 logs, and protozoan cyst removal to 3 logs), no technology exists that will allow operators on the battlefield to purify water from any water source. Compliance with the EPA Standard is defined in Reference 2. The proposed system will include a water storage capability and delivery system, and filtration components, and shall be nuclear-biological-chemical agent resistant. The proposed system must produce at least 800 liters of potable water before maintenance and weigh less than 4 kilograms. A threshold requirement for this system is to make 40 liters of potable water per day from a fresh water source. In addition, the battery load of the special operator is already too high so the system must operate with minimal battery power. The end-state is a lightweight, man-portable, low-power, individual water purification system that will integrate with current and future United States Special Operations Command (USSOCOM) equipment.

PHASE I: Develop concepts for a man-portable, lightweight, low power individual water purification system. Conduct trade studies to evaluate the pros and cons of each concept to include the following factors: size, weight, reliability/durability, purification and filtration capabilities, safety and associated health hazards. Conduct an analysis of these concepts to consider manufacturing cost, life cycle cost, logistics considerations and performance. Demonstrate concept feasibility for the generation of drinking water in a laboratory environment. The Phase I final report will document results of each concept, and include a recommendation for a system that can be demonstrated in Phase II.

PHASE II: Select one concept from Phase I and develop prototypes. Conduct laboratory testing to demonstrate compliance with U.S. EPA Standards for Microbiological Purifiers. Select a concept for further consideration and assemble enough prototypes to conduct a field evaluation. Document results from the Phase II development and field evaluation in the final report.

PHASE III: Manufacture the device for the military, emergency response agencies and commercial sporting industry to develop a large enough consumer base to bring production cost down. The commercial sporting industry has a very large market for water purification devices. Quantities for the commercial market would be large enough to provide economies of scale for the military and civilian market alike.

REFERENCES:
1. Patricia A. Deuster, Teresa Kemmer, Lori Tubbs, Stacey Zeno, Christiane Minnick, Special Operation Forces Nutrition Guide, USSOCOM

2. TB Med 577, Sanitary Control and Surveillance of Field Water Supplies, available at http://armypubs.army.mil/med/DR_pubs/dr_a/pdf/tbmed577.pdf.

3. General water processing information available at www.watertechonline.com

KEYWORDS: Water purification, desalination, portable, lightweight, low power

SB151-003 TITLE: Secure Software Components Leveraging the seL4 Microkernel

TECHNOLOGY AREAS: Information Systems

This topic is eligible for the DARPA Direct to Phase II Pilot Program. Please see section 7.0 of the DARPA instructions for additional information. To be eligible, offerors are required to provide information demonstrating the scientific and technical merit and feasibility of a Phase I project. DARPA will not evaluate the offeror's related Phase II proposal where it determines that the offeror has failed to demonstrate the scientific and technical merit and feasibility of the Phase I project. Offerors must choose between submitting a Phase I proposal OR a Direct to Phase II proposal, and may not submit both for the same topic. Work submitted within the feasibility documentation must have been substantially performed by the offeror and/or the principal investigator (PI).

OBJECTIVE: Build applications that expand the ecosystem of secure software components around the seL4 operating system microkernel.

DESCRIPTION: Recently, seL4, a general-purpose high-performance operating system microkernel, was released to the public as open-source software [1]. Unique to seL4 is its unparalleled degree of assurance, achieved through formal software verification -- the use of mathematical proofs to show that a piece of software satisfies specific properties. As such, seL4's implementation is formally proven functionally correct (bug-free) against its specification, is proven to enforce strong security properties, and its operations have proven safe upper bounds on their worst-case execution times [2]. The open-source release of seL4 includes source code, proofs and specifications, in addition to tools, libraries and example programs that can be used to build trustworthy systems [3].

With seL4 open-sourced, the opportunity emerges to create an extensive community of developers of dependable (safe, secure, reliable) systems, in application areas ranging from national security to automotive, avionics, medical implants, and industrial supervisory control and data acquisition (SCADA) automation. In the defense sector, this technology promises to lead to more secure military systems ranging from unmanned ground, air and underwater vehicles, to weapons systems, satellites, and command and control devices.

However, seL4 alone is not sufficient. It provides a foundation for developing dependable systems, creating a secure software base upon which further secure software layers (i.e., system and application services) can be layered to form a trustworthy system. Consequently, DARPA seeks to develop applications that expand the ecosystem of open-source, secure software components around seL4. Some examples of ecosystem components may include communication protocols, network stacks, trusted boot, and dependable configuration tools, as well as application layers, and so on.

DARPA seeks to have these ecosystem components demonstrated in the context of applications that have potential for national impact (in areas such as listed above). Note that because seL4 enables factored security arguments [4], the components and applications do not necessarily have to be fully formally verified, but they do need to have trust arguments that tie into the formal guarantees that seL4 provides, so that relevant security properties can be established.

PHASE I: Develop a plan for building secure software components in the context of seL4, together with a plan of how these components may be used to create specific secure applications. The Phase I final report will detail the proposed plans, describing the types of components and specific applications targeted, the level of assurance expected to be achieved, and an estimate of the amount of software development and formal verification required.

PHASE II: Develop secure software components together with a demonstration application, on top of seL4 as described in the Phase I final report. Required Phase II deliverables include all documentation and software for the software components, relevant assurance arguments, and a demonstration of the components working with seL4 in the context of the demonstration application. It is strongly preferred that any generally-reusable software components be delivered with an open-source license, while application-specific software components may have more restrictive license terms.

DIRECT TO PHASE II - Offerors interested in submitting a Direct to Phase II proposal in response to this topic must provide documentation to substantiate that the scientific and technical merit and feasibility described in the Phase I section of this topic has been met and describes the potential commercial applications. Documentation should include all relevant information including, but not limited to: technical reports, test data, prototype designs/models, and performance goals/results. Read and follow section 7.0 of the DARPA Instructions. Work submitted within the feasibility documentation must have been substantially performed by the offeror and/or the principal investigator (PI).

PHASE III: Military applications for this technology include: unmanned ground, air and underwater vehicles, weapons systems, satellites, and command and control devices. Commercial applications for this technology include: SCADA systems, medical devices, computer peripherals, communication devices, and vehicles.

REFERENCES:

1. The seL4 website (http://www.sel4.systems) provides extensive background as well as code and proofs.

2. Gerwin Klein, June Andronick, Kevin Elphinstone, Toby Murray, Thomas Sewell, Rafal Kolanski and Gernot Heiser, “Comprehensive formal verification of an OS microkernel”, ACM Transactions on Computer Systems, Volume 32, Number 1, pp. 2:1-2:70, February 2014.

3. Github: https://github.com/seL4

4. Susan D. Alexander, Trust Engineering — Rejecting the Tyranny of the Weakest Link, Proceedings of ACSAC '12, Orlando, FL.

KEYWORDS: seL4, microkernel, operating system, formal verification, dependable systems, open-source software

SB151-004 TITLE: <u>Programming New Computers</u>

TECHNOLOGY AREAS: Information Systems

This topic is eligible for the DARPA Direct to Phase II Pilot Program. Please see section 7.0 of the DARPA instructions for additional information. To be eligible, offerors are required to provide information demonstrating the scientific and technical merit and feasibility of a Phase I project. DARPA will not evaluate the offeror's related Phase II proposal where it determines that the offeror has failed to demonstrate the scientific and technical merit and feasibility of the Phase I project. Offerors must choose between submitting a Phase I proposal OR a Direct to Phase II proposal, and may not submit both for the same topic. Work submitted within the feasibility documentation must have been substantially performed by the offeror and/or the principal investigator (PI).

OBJECTIVE: Define and implement methods by which a set of significant applications can be programmed to execute efficiently on a variety of new and emerging computer architectures.

DESCRIPTION: The space of practical architectures for computing is inflating rapidly. Combinations of latency-optimized processors, throughput-optimized processors including graphics processing units (GPUs), field-programmable gate arrays (FPGAs), networks, and special-purpose accelerators are now employed, or will soon be employed, in systems that support national security. New types of memories (e.g., phase-change memory, spin-transfer torque memory) may change the optimal designs for memory hierarchies. The advent of next generations of complementary metal–oxide–semiconductor (CMOS) fabrication may push fault tolerance and dynamic resource optimizations to higher priorities for designers' attention.

Today it is challenging to enable, by languages and tools, a programmer to write code for a single application targeted to a single advanced architecture. Ideally, a programmer could write source code for any application, and have that code be compilable to run efficiently on any target architecture; this is probably impossible. For example, the avionics software developed for a major Air Force platform was not portable to architectures that differed substantially in any dimension from the initially implemented target. Software on Navy platforms has been found to be very expensive to port to revised versions of their target system architecture. The technologies developed here will result in dramatically improved ability to choose optimally cost-effective target architectures, and in greatly reduced cost for system upgrades. Moreover, because the software is portable, systems will be upgradable in phases, without requiring that all platforms of a given class be simultaneously upgraded.

Innovative solutions are sought to enable, by languages and tools, a programmer to write any of a set of applications – an application domain – so that it is functionally portable and performance portable across a set of target architectures – an architecture domain. A solution may be specific to one application domain and one architecture domain. The bigger the domains, the better. The domains should be relevant to national security applications, including DoD embedded computing.

A body of software is "functionally portable" across an architecture domain if the software can be compiled to execute on any architecture in the domain, and when so executed it will produce correct results. (The exact meaning of "correct results" is a non-trivial issue, especially when approximate computing and timing constraints are involved.) A body of software is "performance portable" across an architecture domain if it is functionally portable across that domain, and it executes with approximately the same relative efficiency across the architecture domain. The "relative efficiency" of a given application on a given target architecture is its efficiency expressed as a fraction of the efficiency of the hypothetical optimal software for that application on that architecture. (The exact meaning of "efficiency" is a non-trivial issue, especially when power, energy, and reliability are included).

It is desirable that whatever languages and tools are provided be productive, in the sense that only reasonable effort is required for a reasonably skilled programmer to write, debug, and tune programs in the application domain. (If technologies are proposed that result in non-deterministic behavior – i.e., the program can behave differently on different executions with the same inputs – then the consequent impact to productivity must be addressed.) Productivity is difficult to quantify; efforts that propose experimentation on human subjects are not desirable.

The proposed technologies must have a plausible path for transition into national security systems. Regarding languages in particular, in order that a programming language have a significant impact, it needs a full suite of mature tools (compilers, debuggers, etc.), a maintenance or standards body to correct and enhance its specification, libraries of useful modules, and a community of users; as a result, transitioning a new language is difficult. Minor additions to or modifications of existing languages are easier to transition.

PHASE I: The Phase 1 final report will specify the problem domain, which is a domain of target architectures and a domain of applications, and will include a technical approach and feasibility analysis for programming those applications to run on those architectures.

It is not required to specify a complete programming environment. It is sufficient to specify and analyze one or a few innovative techniques. Examples of such techniques are

- A method by which a programmer can determine which of two bodies of code will execute with greater efficiency across the target architecture domain.
- A method for generating relatively efficient FPGA code from a conventional programming language. (See above for the definition of relative efficiency.)
- A method for maintaining relative efficiency of an application across a variety of cache hierarchies.
- A method to automate the use of scratchpad memory, when it's available.

PHASE II: The minimum required product for the end of Phase II is a prototype implementation of the techniques defined in Phase I. This demonstration shall apply to at least three applications within the specified application domain, and at least three target architectures within the specified architecture domain. The demonstration is intended to establish that the techniques that have been developed provide material advancement in the achievement of performance portability across the domains of interest.

DIRECT TO PHASE II - Offerors interested in submitting a Direct to Phase II proposal in response to this topic must provide documentation to substantiate that the scientific and technical merit and feasibility described in the Phase I section of this topic has been met and describes the potential commercial applications. Documentation should include all relevant information including, but not limited to: technical reports, test data, prototype designs/models, and performance goals/results. Read and follow section 7.0 of the DARPA Instructions. Work submitted within the feasibility documentation must have been substantially performed by the offeror and/or the principal investigator (PI).

PHASE III: A profusion of new computing architectures are becoming available for use in DoD systems. These architectures have great promise in new capabilities, but the architectures will be of little use unless they can be cost-effectively programmed.

Commercial applications of the technologies developed include software in an automobile that needs to be performance portable across successive generations of the computing platforms within the automobile. Also, software that is intended to run in a cloud environment should be performance portable across the set of platforms that the cloud may provide.

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1. Michael Garland, Manjunath Kudlur, and Yili Zheng, "Designing a Unified Programming Model for Heterogeneous Machines" http://conferences.computer.org/sc/2012/papers/1000a064.pdf

2. Matteo Frigo and Steven G. Johnson, "The Design and Implementation of FFTW3" http://www.fftw.org/fftw-paper-ieee.pdf

3. B. Chamberlain, D. Callahan, and H. Zima, "Parallel programmability and the Chapel language," Int. J. High Perform. Comput. Appl., vol. 21, no. 3, pp. 291–312, Aug. 2007.

4. P. Charles, C. Grothoff, V. Saraswat, C. Donawa, A. Kielstra, K. Ebcioglu, C. von Praun, and V. Sarkar, "X10: An Object-Oriented Approach to Non-uniform Cluster Computing," ACM SIGPLAN Notices, vol. 40, no. 10, pp. 519–538, Oct. 2005.

KEYWORDS: software, portability, efficiency, multicore, memory hierarchy, performance portable, architecture domain, application domain

SB151-005 TITLE: Collaborative Interference Cancellation for Group Communications

TECHNOLOGY AREAS: Information Systems, Sensors

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), which controls the export and import of defense-related material and services. Offerors must disclose any proposed use of foreign nationals, their country of origin, and what tasks each would accomplish in the statement of work in accordance with section 5.4.c.(8) of the solicitation.

This topic is eligible for the DARPA Direct to Phase II Pilot Program. Please see section 7.0 of the DARPA instructions for additional information. To be eligible, offerors are required to provide information demonstrating the scientific and technical merit and feasibility of a Phase I project. DARPA will not evaluate the offeror's related Phase II proposal where it determines that the offeror has failed to demonstrate the scientific and technical merit and feasibility of the Phase I project. Offerors must choose between submitting a Phase I proposal OR a Direct to Phase II proposal, and may not submit both for the same topic. Work submitted within the feasibility documentation must have been substantially performed by the offeror and/or the principal investigator (PI).

OBJECTIVE: Develop the system components for enabling disconnected platforms to collaboratively null interference in order to communicate from one collaboration group to another.

DESCRIPTION: There is a critical military need for communications in the presence of unintentional or deliberate interference to wireless systems. In particular, for the military wireless systems that need to communicate over long distances to other flights, platoons or to a command and control platform or command post, interference often limits communication to within the flight or platoon, denying the ability to communicate to radios outside the group. Current interference suppression focuses on the ability of each individual radio to cancel interference. A scalable technical approach is needed that can collaboratively cancel interference for a group of collaborative radios so military wireless communications can take place over large distances in the presence of interference. This technology is applicable to future communications systems developed by the Army, Air Force, and Navy.

Wireless communication systems are under increased pressure from intentional or unintentional interference. The interference affects multiple radios within proximity of each other. Communications usually can take place within closely spaced groups of radios traveling as a group but no single radio has the ability to communicate to a distant radio due to limitations in transmit power or received power at the receiver due to interference. However, groups of radios can collaboratively share interference information and form distributed arrays that can suppress interference and use multichannel techniques to communicate to distant radios using techniques such as those developed for Multiple Input Multiple Output (MIMO) communications.

Both the desired signals and the unwanted interference are correlated at multiple receiving nodes within a group. This correlation can be leveraged to cancel or null the interference and consequently improve system performance. System performance can be improved by increasing the energy received at the distant radio group or by nulling interference at the receiving radio group. This nulling capability is particularly useful for asymmetric links where the return link and more advantaged radio has the power to transmit over great distances and has greatly reduced interference but the received signal at the forward radio group is disrupted by interference.

Preliminary implementations of distributed MIMO systems focused on capacity in benign scenarios and are generally limited to closed, narrowly focused systems. Existing work does not address the complexity of radios automatically negotiating collaboration groups and roles or the advanced signal processing required to opportunistically suppress interference and increase energy to a particular location in order to maximize the link characteristics. Further, existing work does not show how different groups can optimally communicate given this information.

For this effort, proposed solutions should assess the trade-off between inter-group communications to setup and maintain a collaborative multi-antenna group with differing relative motion and the relative motion of distant groups. Proposed solutions should quantify the amount of interference suppression (both in terms of interference power levels and number of distinct interferers) possible in addition to the inter-group communication bandwidth and relative velocity limit, as well as suggest optimization techniques for using some or all group members for a single communications link, multiple communications links and non-communication suppression only group members. In addition, the research should address the system impacts of maintaining synchronization between radios within the collaborative group. Also of interest is the ability to coordinate transmissions such that the desired signal is delivered to a desired location, as well as interference directed to specific alternate locations. Modeled scenarios should not be limited to only two communicating groups, but potentially several groups needing to communicate simultaneously.

Analysis should be supported by experiments with actual radios, where motion can be induced or emulated to varying degrees of fidelity. Performance of desired group members in regards to the actual task should be quantified including phase noise and energy on target and interference suppression versus theoretical.

PHASE I: Develop the necessary algorithms to perform multi-platform cooperative interference recognition, interference estimation, processing, and cancellation and/or nulling. Conduct simulations to demonstrate feasibility and relative performance gains as a function of frequency, bandwidth, communication range, interference levels, and number of interferers. Quantify the required communications and the required processing to implement the algorithms developed under this effort in the Phase I final report.

PHASE II: Implement the algorithms developed in Phase I on a prototype system. Evaluate performance of the algorithms for a variety of interference conditions including the impact on performance when using four or more platforms. Include recommendations for transitioning the algorithms to operational systems in the Phase II final report.

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PHASE III: The DoD/Military application is not only in the ability of tactical radios to operate in the presence of jamming, but also other forms of electromagnetic interference that may result from other communications systems or radar systems in the same spectrum band. Leveraging collaborative interference suppression has great potential benefits in commercial applications, both for licensed commercial cellular systems and for unlicensed wireless access points. The ever-growing demand for wireless services, particularly for mobile devices, is driving technology to be more spectrally efficient as well as adaptive to changing channel conditions. In extending and adding advanced collaboration features into the physical layer, the user can experience greater performance without knowing devices within an area are collaborating together at the physical layer. Such techniques can also enable coexistence of multiple systems in overlapping spectrum.

REFERENCES:
1. Ozgur, et al., “Spatial Degrees of Freedom of Large Distributed MIMO Systems and Wireless Ad hoc Networks”

2. Dohler, et al., “A Resource Allocation Strategy for Distributed MIMO Multi-Hop Communication Systems”, IEEE Communications Letters, VOL. 8, NO. 2, February 2004

3. Rusek, et al., “Scaling up MIMO: Opportunities and Challenges with Very Large Arrays”, 16 Jan 2012

KEYWORDS: Distributed communications, Multiple Input Multiple Output (MIMO), interference suppression, collaborative communications, massive MIMO

SB151-006 TITLE: <u>Miniature Optical Guidance & Navigation</u>

TECHNOLOGY AREAS: Air Platform, Sensors

This topic is eligible for the DARPA Direct to Phase II Pilot Program. Please see section 7.0 of the DARPA instructions for additional information. To be eligible, offerors are required to provide information demonstrating the scientific and technical merit and feasibility of a Phase I project. DARPA will not evaluate the offeror's related Phase II proposal where it determines that the offeror has failed to demonstrate the scientific and technical merit and feasibility of the Phase I project. Offerors must choose between submitting a Phase I proposal OR a Direct to Phase II proposal, and may not submit both for the same topic. Work submitted within the feasibility documentation must have been substantially performed by the offeror and/or the principal investigator (PI).

OBJECTIVE: Develop a practical optical guidance and navigation suite for small unmanned air vehicles (UAVs). Leveraging recent advances in miniaturization and sensing, such as small LADAR, and bio-inspired landing and collision avoidance could enable a small, low-power-consumption navigation suite capable of delivering affordable, robust and unassisted airborne navigation.

DESCRIPTION: Ensuring safe flight for unmanned vehicles historically relies on external assistance such as remote piloting, or on heavy and power-intensive sensing and control modalities such as radar and multi-axis precision inertial measurement units (IMUs), or relies on deterministic plans such as those enabled by terrain maps and precision GPS. The size, weight and power and cost (SWaP-C) limitations for the overall navigation function hinders widespread application of autonomous navigation in particular for smaller (<55 lb) platforms. Even where small partial solutions exist, costs may exceed the cost of the platform itself and can limit user willingness to employ them.

Cutting the persistent tether to an operator requires both obstacle avoidance for assured safety, and dynamic mapping and navigation for utility. Recent trends in sensor miniaturization offer superior performance along with reduced SWaP-C burden. Increased on-board computational capabilities available even on smaller unmanned air systems (UAS) enable sophisticated algorithms that reduce the need for remote piloting or very high performance sensors.

Object and pattern recognition advances enable mapping and localization tasks to be performed quickly. On larger platforms, they have been used for identification of, and flights to, safe landing zone in programs such as the Office of Naval Research (ONR)'s Autonomous Aerial Cargo/Utility System (AACUS) program. Similarly non-cooperative sense-and-avoid technologies have relied on heavy radar, but the capabilities of multi-spectrum optical techniques are rapidly improving as computational availability enables new real-time algorithms.

Specifically, lower SWaP-C sensors have been developed in areas such as LADAR, inertial sensing and broad-spectrum optics. These sensors may be noisier and less accurate than their larger counterparts, but they have been shown to offer good solutions when collectively employed with appropriate processing algorithms. For example, novel optical sensing techniques have been borrowed from biological flyers such as Odonata-inspired horizon sensing, and the use of optic flow for precision landing and obstacle avoidance. Clever architectures have been shown to overcome problems with widely varying lighting conditions, and visual variations in targets and obstacles. Open architectures also offer the potential to reduce costs by enabling rapid incorporation of new sensors and applications, tailoring of sensor suites to particular applications, and new modalities of cooperation between flight vehicles.

Specific areas of interest in this SBIR include:

- Development of reduced SWaP-C optical sensors such as LADARs and optical sensors that exploit novel aspects of the spectrum and wide field of view.
- Development of algorithms to extract useful guidance and navigation data from low SWaP-C optically based sensor suites
- Exploitation and demonstration of open and flexible architectures that allow for rapid changes in sensors and algorithms
- Exploitation of advanced sensors and control modalities

The program objective is a complete navigation system with viability demonstrated via a series of flight tests and thorough cost analysis.

Specification development is a Phase I activity, however benchmark performance targets include:

- Probability of detection of potentially interfering airborne object: > 98%
- Target weight: under 8 lb
- Assured avoidance distances sufficient to ensure safe flight

The objective by the completion of Phase II is aerial demonstration of a robust, adaptable small-SWaP, low-cost optically based sensor package capable of providing safe and reliable flight from takeoff to landing without real-time supervision or intervention.

PHASE I: Validate the feasibility of the proposed approach to a low SWaP-C optical guidance and navigation system to support autonomous flight. The following activities should be addressed in support of this goal:

- Develop the design of a sensor package that incorporates optical and other sensors and supporting algorithms and validate their viability via simulation or hardware demonstration
- Develop a hardware and software specification for a Phase II brassboard system and a Phase III prototype system and estimate their SWaP, performance and cost
- Identify development needs and create a plan to address them in Phase II, including a brassboard specification and a demonstration plan. The demonstration plan should systematically mature key technologies through the remainder of Phase I and Phase II and culminate in a system-level flight demonstration in Phase II

Deliverables include a report documenting Phase I accomplishments and technology maturation needs and plans, and commercialization opportunities and approaches.

PHASE II: Demonstrate the performance capabilities of the navigation suite components and architecture that includes the following activities:

- Build a breadboard sensor suite
- Simulate the performance through a simple flight profile
- Demonstrate components or systems in an operationally representative environment
- Demonstrate the ability of the architecture to adapt to a new sensor

Demonstrate the ability to autonomously fly a waypoint route from takeoff to landing, avoiding obstacles without outside intervention that includes the following activities:

- Build a lighter-weight brassboard system
- Integrate the guidance and navigation suite into a flying platform
- Fly system through complete profile, from launch to recovery without outside intervention
- Fly new routes in varied and extreme conditions avoiding obstacles not known beforehand
- Collect performance data such as actual avoidance distances as compared to the design specifications

The results of the Phase II demonstration activities should be used to develop a design for a Phase III commercial system.

Deliver a final report detailing the design, test and demonstration results, technology maturation needs and a Phase III commercialization plan.

DIRECT TO PHASE II - Offerors interested in submitting a Direct to Phase II proposal in response to this topic must provide documentation to substantiate that the scientific and technical merit and feasibility described in the Phase I section of this topic has been met and describes the potential commercial applications. Documentation should include all relevant information including, but not limited to: technical reports, test data, prototype designs/models, and performance goals/results. Read and follow section 7.0 of the DARPA Instructions. Work submitted within the feasibility documentation must have been substantially performed by the offeror and/or the principal investigator (PI).

PHASE III: As cost decreases and performance increases, accompanied by elimination of the need for remote piloting, the viability of several CONOPS increase:

- Communication relay for small units
- Forward scouting with attritable platforms
- Autonomous aerial soldier resupply
- Perimeter defense against hostile UAVs
- Collaborative intelligence, surveillance and reconnaissance (ISR)

The availability of a flexible and affordable optical navigation suite would facilitate rapid development of both sensors and algorithms. Lowering the barrier to entry for navigation researchers and sensor developers would provide a broad and active user base.

Automated route flying would likely find use in two commercial application areas: (1) remote sensing, and (2) object delivery or retrieval. For example, agricultural and natural resource monitoring would become more affordable owing to autonomous systems operating without a large human operator cost burden. The effectiveness of search and rescue operations would be greatly enhanced with small UAVs that could fly over inhospitable terrain at low altitudes in areas with limited communications options. Similarly, delivery of medical supplies and mail to remote locations could be more affordable with small UAVs.

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2. Utopia Compression, “Sense and Avoid” http://www.utopiacompression.com/technologies/sense_and_avoid.php, accessed 19 Jun 2014.

3. Mickael, Q., Optical flow estimation using insect vision based parallel processing, M.S. Thesis, University of Wollongong, 2011. http://ro.uow.edu.au/theses/3410

KEYWORDS: Unmanned aircraft, optical sensing, affordability, guidance, navigation